THE GEOLOGY OF THE WHITE CLIFFS–MT. JACK–PEERY LAKE AREA, NEW SOUTH WALES

J. RADE

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(Plate VII)

[Read 28th June, 1967]

Synopsis

The area lies north of the Darling River about 50 miles north of Wilcannia. Pleistocene to Recent, Tertiary, Cretaceous and Devonian sediments outcrop in the area. The hills in the Mt. Jack-Peery Lake area consist of Upper Devonian rocks. The Mulga Downs Group can be divided into the Momba Sandstone and the Paroo Sandstone. The main structural feature in the Mt. Jack-Peery Lake area is the Mt. Jack anticline. Two anticlines are present in the White Cliffs area. Palynological investigations show that the centre of the White Cliffs anticline consists of sediments belonging to Cretaceous Roma Formation, and the flanks of this anticline of Tambo Formation.

INTRODUCTION

The area considered in this paper lies in the north-western part of New South Wales, north of the Darling River and about 50 miles north of Wilcannia. Compared with the surrounding plains it is fairly hilly, the highest point being 725 feet above sea level. The average rainfall is nine inches per year, which produces semi-arid country with sand dunes ; however, the country supports some sheep and cattle. On geological grounds it may be divided into two regions : the Mt. Jack-Peery Lake area characterized by Devonian sediments, and the White Cliffs area where Cretaceous sediments are dominant with Devonian rocks outcropping only near its eastern edge (Fig. 1).

Very little has been written about this area. Kenny (1934) mentioned it in describing the geology and sub-surface waters of the West Darling district ; Relph (1959) described the White Cliffs opal field ; the author (Rade, 1964) described fish from the Mt. Jack-Peery Lake area, fixing the age of the sediments there as uppermost Devonian. Mulholland (1940) described the geology and underground water resources of the East Darling district, which contains Devonian rocks similar to those of the Mt. Jack-Peery Lake area ; the author (Rade, 1954) has described an area north of the Darling River between longitudes 145° E. and 149° E. which lies to the north-east of the area considered in this paper.

GEOLOGY

Pleistocene to Recent, Tertiary, Cretaceous and Devonian sediments outcrop in the area.

Pleistocene to Recent

These sediments consist of alluvium, clay, sand and gravel. Silt and mud are widely distributed on the plains and floodouts. Sand has accumulated in the flat valleys ; red sand dunes have been formed locally where sand has been derived from the disintegration of Devonian sandstones. The conglomeratic layers encountered in the Upper Devonian sandstones weather to sub-rounded quartz gravels, and the more resistant Upper Devonian sandstones form hard sandstone blocks.

Tertiary

The Tertiary is represented by sediments of the " Eyrian Series ", mostly shales and secondary quartzites which cap the Lower Cretaceous deposits in the White Cliffs area ; they are generally between 10 and 30 feet thick.

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Lower Cretaceous

On the plains the Cretaceous sediments are usually masked by Pleistocene to Recent deposits. They are exposed in canyons 200 feet deep in the White Cliffs area, where they consist of shales with subordinate white, fine-grained sandstones.

Lower Cretaceous sediments are known also at Momba. Kenny (1934, p. 76) estimated the thickness of Lower Cretaceous sediments in the White Cliffs-Bootra-Momba area to be 750 feet, but a bore at Momba penetrated 2,000 feet of Cretaceous sediments without reaching their base (Pittman, 1895). Lower Cretaceous sediments occur as outliers on the western part of the Peery Hills,

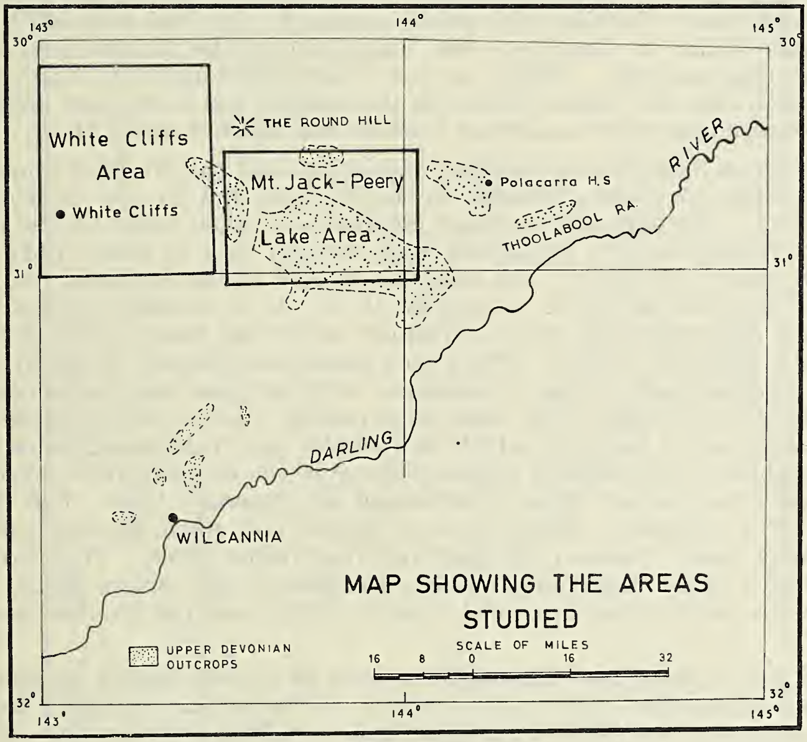

Fig. 1.

where they overlie Upper Devonian sediments. Here they are easily recognized by their dirty yellow to greyish-white colour on weathered surfaces. Sediments of this age also occur at the Round Hill four miles north of Peery Lake. Partly lateritized shales form the low, roughly east-west trending ridges to the east of the Round Hill.

Upper Devonian

The hills in the Mt. Jack-Peery Lake area consist of Upper Devonian rocks. Kenny (1934) divided the Devonian sediments of the West Darling district into two stages: the Gnalta Stage (lower) and the Mootwingee Stage (upper). Mulholland (1940) divided the Devonian rocks of the Cobar area into the Amphitheatre (lower) and Mulga Downs (upper) stages. Kenny's Mootwingee Stage is approximately equivalent to Mulholland's Mulga Downs Stage. On its latest (1962) map of New South Wales, the Geological Survey of N.S.W. shows the Mulga Downs Group as Upper Devonian.

The *Mulga Downs Group* outcrops widely in the Mt. Jack-Peery Lake area. On lithological grounds, it can be divided into the Momba Sandstone and the Paroo Sandstone.

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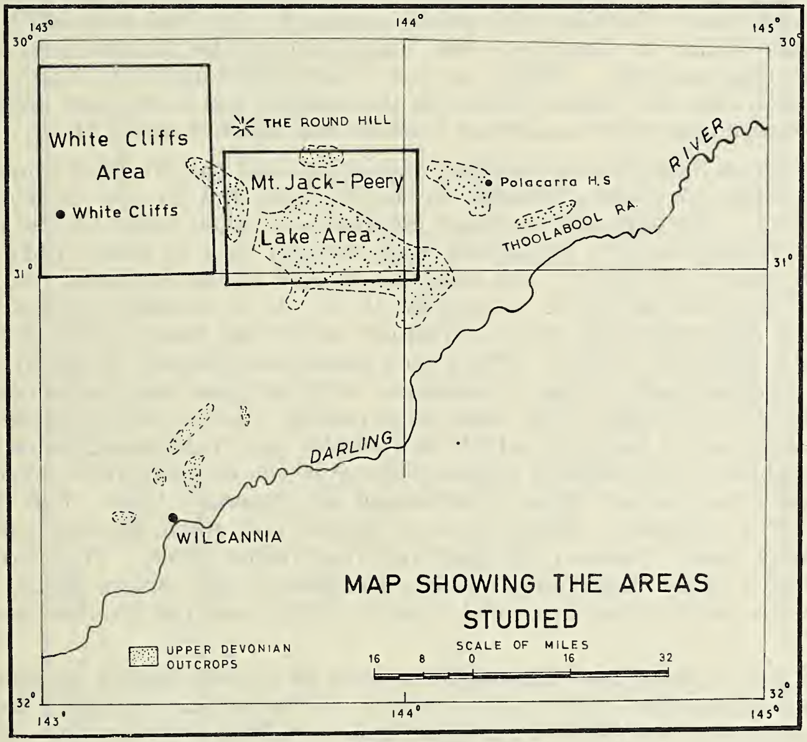

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The Momba Sandstone is about 4,000 feet thick ; its type locality is four miles south-west of the Mt. Pleasant homestead on the southern end of the Mt. Orr anticline. The name of the Momba Sandstone is taken from the Momba homestead, 40 miles north of Wilcannia. It extends from south-west of Peery Lake, lat. 30° 49′ S., long. 143° 30′ E., to the east end of the Thoolabool Range, lat. 30° 50′ S., long. 144° 30′ E. It represents the upper part of the Upper Devonian ; it is overlain by Cretaceous rocks, and underlain by the Paroo Sandstone. It is exposed also to the north-east of Momba, and at the southern end of the Coorpooka Lake in the Black Hills. The Upper Devonian rocks at Polacarra, Thoolabool Range and south of Mt. McPherson belong to it. It consists of rather soft, friable, medium- to fine-grained quartz sandstones with sub-angular quartz pebbles ; the pebbles range in size from one-eighth to one and a half inches in diameter. The basal part of the Momba Sandstone is decidedly conglomeratic. Higher up it is cross-bedded and often massive, with layers up to nine feet thick. Between the massive sandstones are flaggy fine-grained brown and white sandstones between one and five inches thick.

The Paroo Sandstone is typically exposed around the Mt. Jack homestead ; the most widely exposed sediments on the Mt. Jack and Mt. Orr anticlines also belong to it. The name of the Paroo Sandstone is taken from the Paroo River north of Wilcannia. Its uppermost beds outcrop west of Peery Lake at lat. 30° 43′ S., long. 143° 25′ E. ; its base was located in the Mt. Jack No. 1 Bore at 3,250 feet, lat. 30° 45′ S., long. 143° 45′ E. It is overlain by the Momba Sandstone and underlain by an unnamed sandstone found below 3,250 feet in the Mt. Jack No. 1 Bore. The Paroo Sandstone consists of brown, mostly fine- to medium-grained quartz sandstones with irregular clay inclusions and a few casts of salt crystals. The sandstones contain scattered sub-angular quartz pebbles and pebble layers in which the pebbles are up to three inches across. A few pebbles of sub-rounded quartzite occur in the conglomeratic layers ; the pebbles of quartzite are more rounded and are generally larger than those of quartz. The sandstones are often cross-bedded and ripple marked, and often form flaggy bands between one-half and four inches thick. They are inter-bedded with shaly fine-grained quartz sandstones and brown shale. These rocks are very soft and easily eroded, forming valleys between resistant sandstone ridges.

The top of the Paroo Sandstone consists of a cross-bedded conglomeratic sandstone interbedded with brown, medium- to coarse-grained quartz sandstone lenses containing scattered sub-angular quartz pebbles between one and three inches in diameter. The lenses of sandstone are up to three feet three inches thick ; the sub-angular quartz pebbles in them are generally about one inch across. The thickness of the Paroo Sandstone is estimated to be about 5,000 feet. Remains of fossil armoured fish found in the Paroo Sandstone by the author (Rade, 1964) include *Phyllolepis*, *Groenlandaspis*, *Holonema* and *Striacanthus*, showing it to be of Famennian age. The fossils were found in hard brown, flaggy, fine-grained quartz sandstones at three main localities, two of them on the Mt. Jack anticline and one on the Mt. Orr anticline (Fig. 2).

Silicification of the sediments of the Paroo Sandstone is common. Kenny (1934, p. 60) observed silicification in the sediments of the West Darling district : " Silica bearing solutions probably entering the sediments per medium of the fissure or fissures resulting from earth movement." Concerning the thin coating of siliceous material often found on slickensides in the area he says : " Many of the slickensided faces exhibit a thin coating of siliceous material ; while small and irregular veins of similar composition are common within the sandstones in areas contiguous to some plane or locus of intense deformation. All these features, however, are by no means widespread." Very characteristic polygonal fracturing is widespread on surfaces of sandstones of the Paroo Sandstone which have been case-hardened by secondary silicification (Plate VII).

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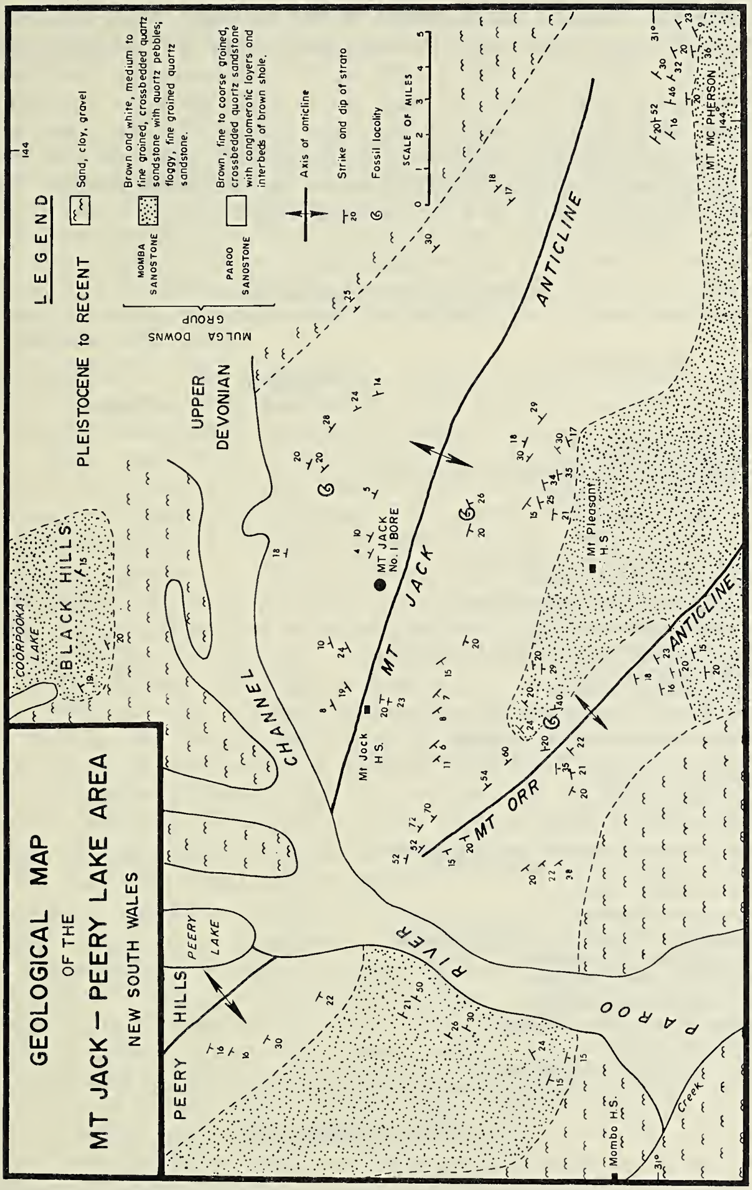


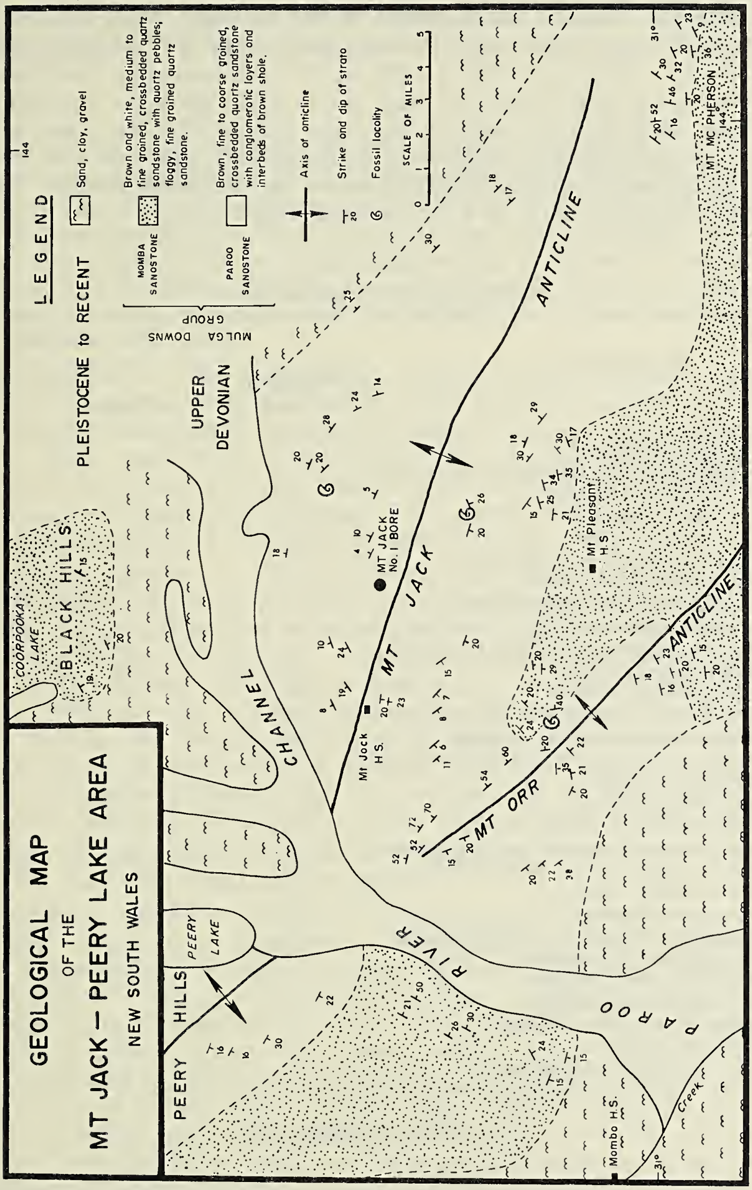
Fig. 2.

STRUCTURE
Mt. Jack-Peery Lake Area

Folding

The main structural feature in the area is the Mt. Jack anticline. Its axis trends approximately N. 80° W. ; the Paroo Sandstone is exposed in its core. Both limbs of the anticline show average dips between 4° and 25°. Dips up to 52° occur north of Mt. McPherson. On the southern flank of the anticline about two and a half miles north-east of Mt. Pleasant homestead dips up to 35° were found.

The north-eastern limb of the Mt. Orr anticline is the steeper. Dips up to 72° were found on this limb at its north-western end, 68° in the middle and 42°



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at the south-eastern end, where it dips under Pleistocene to Recent deposits. The south-western flank of the anticline is not as steep, with dips up to 25° at its north-western end, 20° to 38° in the middle, and 29° at the south-eastern end.

Both the anticlines in the Mt. Jack-Peery Lake area are closed structures. Although the north-eastern part of the east end of the Mt. Jack anticline is covered by younger deposits, the cover is apparently thin and the trend of the Upper Devonian rocks is clearly discernible on aerial photographs. These show that the Mt. Jack anticline is a well-closed structure.

TABLE 1

Distribution of Sporomorphs

Sporomorphs	White Cliffs Anticline		
	Western Flank	Centre	Eastern Flank
Cyathidites australis Couper	+	..	..
Stereisporites antiquasporites (Wilson and Webster)	+	..	+
Leptolepidites verrucatus Couper	+	+	+
Leptolepidites major Couper	+	..	..
Osmundacidites mollis (Cookson and Dettmann)	+	..	..
Baculatisporites comaumensis (Cookson)	+	+	+
Neoraistrickia truncatus (Cookson)	+	+	+
Tripartina cf. *T. variabilis* Maljavikina	..	..	+
Faveosporites canalis Balme	+	..	+
Lycopodiumsporites austroclavatidites (Cookson)	+	+	+
Reticulatisporites pudens Balme	+	..	+
Acanthotriletes levidensis Balme	+	+	..
Dictyotosporites complex Cookson and Dettmann	+	..	..
Cicatricosisporites australiensis (Cookson)	+	..	..
Cicatricosisporites pseudotripartitus (Bolkhovitina)	+	..	..
Ischyosporites crateris Balme	..	..	+
Cingutriletes clavus (Balme)	..	+	..
Contignisporites cooksonii (Balme)	+	..	..
Crybelosporites striatus (Cookson and Dettmann)	+	..	+
Laevigatosporites ovatus Wilson and Webster	+	..	+
Reticuloidosporites arcus (Balme)	+	..	..
Pilasporites marcidus Balme	+	..	..
Coptospora paradoxa (Cookson and Dettmann)	+	..	..
Rouseisporites radiatus Dettmann	+	..	..
Tsugaepollenites dampieri (Balme)	..	+	+
Vitreisporites pallidus (Reissinger)	+	..	..
Microcachryidites antarcticus Cookson	+	..	..
Cycadopites nitidus (Balme)	+	+	+
Classopollis cf. *C. torosus* (Reissinger)	..	+	..

The White Cliffs Area

Folding

Two anticlines affecting the Tertiary "Eyrian Series" sediments are present in this area. A large north-north-east trending anticline east of White Cliffs is here named the White Cliffs anticline. A smaller anticline south-east of White Cliffs, just east of the southern end of the White Cliffs anticline, is named the Bunker Hill anticline.

The *White Cliffs anticline* has been traced from eight miles south of White Cliffs to about 22 miles north-east of White Cliffs. At its southern end the limbs dip at between 10° and 20°; in the central part dips are between 7° and 16°; at the northern end dips are between 10° and 22°.

The *Bunker Hill anticline* is a small west-north-west trending structure. Its northern side dips at between 9° and 26°, and the southern side at 9° to 17°.

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A north-south syncline west of White Cliffs extends for some distance to the north.

Faulting

A meridional fault, here named the *Pulpa Fault*, cuts the middle part of the White Cliffs anticline. It shows evidence of right lateral type horizontal movements which have displaced part of the White Cliffs anticline. The Pulpa Fault is quite long.

Palynology of White Cliffs Anticline

Twenty-nine sporomorphs (Table 1) were encountered in the five analysed samples from the different portions of the White Cliffs anticline (Fig. 3). Of the detected sporomorphs, four are of importance for closer dating of the exposed deposits on the White Cliffs anticline. These are as follows : *Laevigatosporites ovatus* Wilson and Webster, *Cicatricosisporites pseudotripartitus* (Bolkhovitina,) *Crybelosporites striatus* (Cookson and Dettmann) and *Acanthotriletes levidensis* Balme.

The occurrence of the sporomorph *Crybelosporites striatus* (Cookson and Dettmann) on both flanks of the White Cliffs anticline shows that the strata which are exposed there could not be older than the upper horizons of the Roma Formation. This conclusion is based on the vertical distribution of this sporomorph in the Great Artesian Basin where, according to Dettmann (1963, p. 81), it occurs in the upper horizons of the Roma Formation with a vertical extension into the Winton Formation.

The exposed sediments on both flanks of the White Cliffs anticline can be more closely dated by the occurrence of *Laevigatosporites ovatus* Wilson and Webster and *Cicatricosisporites pseudotripartitus* (Bolkhovitina), which do not occur below the Tambo Formation. *Laevigatosporites ovatus* Wilson and Webster is confined to the Tambo and Winton Formations in the Great Artesian Basin (Dettmann, 1963, p. 86). *Cicatricosisporites pseudotripartitus* (Bolkhovitina) also occurs there in the Tambo Formation according to Dettmann (1963, p. 55). The first of these abovementioned sporomorphs represents a very common form on the western as well as on the eastern flanks of the White Cliffs anticline. The second one has been found only on the western flank of this anticline.

It is clear that the strata exposed on both flanks of the White Cliffs anticline are not older than the Tambo Formation.

Leptolepidites verrucatus Couper, *Baculatisporites comaumensis* (Cookson), *Neoraistrickia truncatus* (Cookson), *Lycopodiumsporites austroclavatidites* (Cookson), *Acanthotriletes levidensis* Balme, *Cingutriletes clavus* (Balme), *Tsugaepollenites dampieri* (Balme), *Cycadopites nitidus* (Balme) and *Classopollis* cf. *C. torosus* (Reissinger) were found in the centre of the White Cliffs anticline. *Acanthotriletes levidensis* Balme has been recorded from the Lower Cretaceous in Western Australia and has not been found in the Jurassic (Balme, 1957, p. 18). The other recorded forms have a fairly wide vertical range in the Mesozoic sediments and for this reason they are not conclusive ; however, according to the occurrence of *Acanthotriletes levidensis* Balme and because no other forms were found which would be characteristic for the Tambo Formation, the strata exposed in the centre of the White Cliffs anticline were accepted as belonging to the Roma Formation.

Palaeozoic Palaeogeography and Sedimentation

The Middle Cambrian sea reached the area west of White Cliffs. This has been established by the presence of the Cambrian trilobites *Pagetia significans* and *Dorypyge* (?) *tenella* in the Mootwingee area (Warner and Harrison, 1961). Ordovician sediments have been found in the same area (Geol. Surv. N.S.W. 1962). Öpik (1957) has shown that the Cambrian tends to be characterized by north-south trends and the Ordovician by east-west trends in Central Australia. The author (Rade, 1957) has observed similar trends in the faulting of Cambrian and Ordovician sediments in the Amadeus Basin south-east of Alice Springs. A meridional fault lies in the central part of the White Cliffs area (Fig. 3).

Faulting

A meridional fault, here named the *Pulpa Fault*, cuts the middle part of the White Cliffs anticline. It shows evidence of right lateral type horizontal movements which have displaced part of the White Cliffs anticline. The Pulpa Fault is quite long.

Palynology of White Cliffs Anticline

Twenty-nine sporomorphs (Table 1) were encountered in the five analysed samples from the different portions of the White Cliffs anticline (Fig. 3). Of the detected sporomorphs, four are of importance for closer dating of the exposed deposits on the White Cliffs anticline. These are as follows : *Laevigatosporites ovatus* Wilson and Webster, *Cicatricosisporites pseudotripartitus* (Bolkhovitina,) *Crybelosporites striatus* (Cookson and Dettmann) and *Acanthotriletes levidensis* Balme.

The occurrence of the sporomorph *Crybelosporites striatus* (Cookson and Dettmann) on both flanks of the White Cliffs anticline shows that the strata which are exposed there could not be older than the upper horizons of the Roma Formation. This conclusion is based on the vertical distribution of this sporomorph in the Great Artesian Basin where, according to Dettmann (1963, p. 81), it occurs in the upper horizons of the Roma Formation with a vertical extension into the Winton Formation.

The exposed sediments on both flanks of the White Cliffs anticline can be more closely dated by the occurrence of *Laevigatosporites ovatus* Wilson and Webster and *Cicatricosisporites pseudotripartitus* (Bolkhovitina), which do not occur below the Tambo Formation. *Laevigatosporites ovatus* Wilson and Webster is confined to the Tambo and Winton Formations in the Great Artesian Basin (Dettmann, 1963, p. 86). *Cicatricosisporites pseudotripartitus* (Bolkhovitina) also occurs there in the Tambo Formation according to Dettmann (1963, p. 55). The first of these abovementioned sporomorphs represents a very common form on the western as well as on the eastern flanks of the White Cliffs anticline. The second one has been found only on the western flank of this anticline.

It is clear that the strata exposed on both flanks of the White Cliffs anticline are not older than the Tambo Formation.

Leptolepidites verrucatus Couper, *Baculatisporites comaumensis* (Cookson), *Neoraistrickia truncatus* (Cookson), *Lycopodiumsporites austroclavatidites* (Cookson), *Acanthotriletes levidensis* Balme, *Cingutriletes clavus* (Balme), *Tsugaepollenites dampieri* (Balme), *Cycadopites nitidus* (Balme) and *Classopollis* cf. *C. torosus* (Reissinger) were found in the centre of the White Cliffs anticline. *Acanthotriletes levidensis* Balme has been recorded from the Lower Cretaceous in Western Australia and has not been found in the Jurassic (Balme, 1957, p. 18). The other recorded forms have a fairly wide vertical range in the Mesozoic sediments and for this reason they are not conclusive ; however, according to the occurrence of *Acanthotriletes levidensis* Balme and because no other forms were found which would be characteristic for the Tambo Formation, the strata exposed in the centre of the White Cliffs anticline were accepted as belonging to the Roma Formation.

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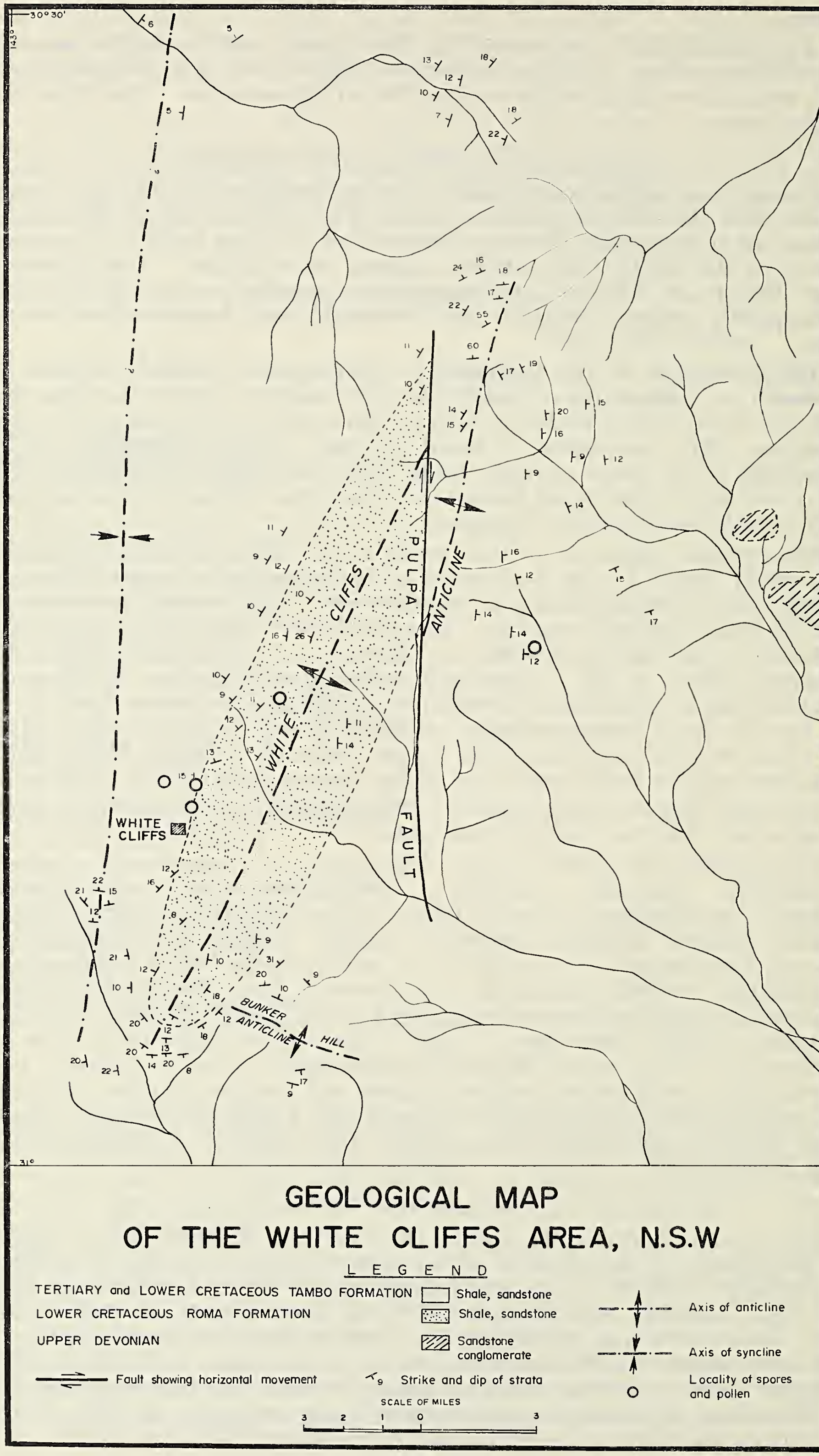
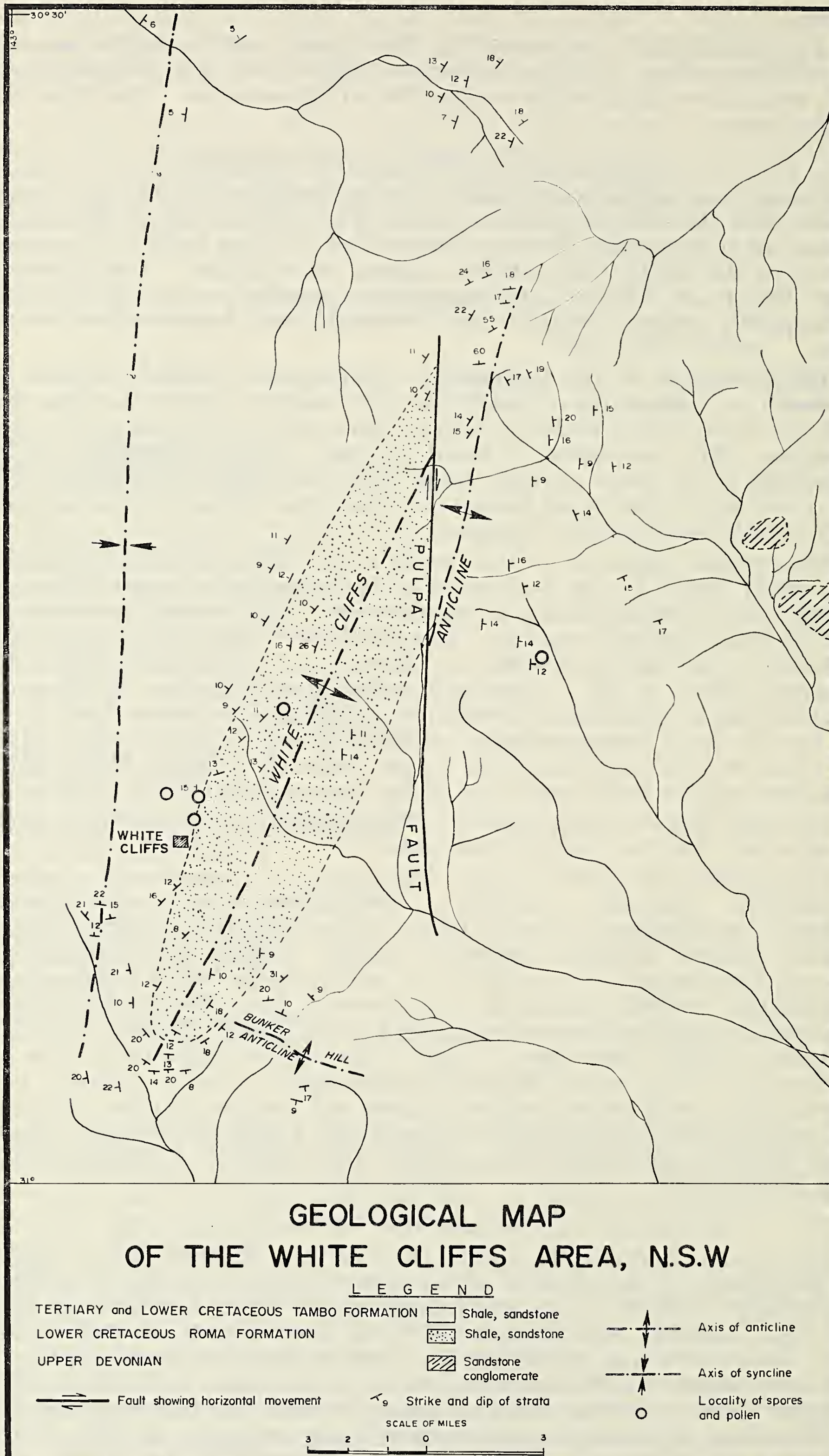


30°30'
143°
31°
WHITE CLIFFS
WHITE CLIFFS
PULPA
ANTICLINE
FAULT
BUNKER HILL
ANTICLINE
GEOLOGICAL MAP
OF THE WHITE CLIFFS AREA, N.S.W
LEGEND
TERTIARY and LOWER CRETACEOUS TAMBO FORMATION
Shale, sandstone
LOWER CRETACEOUS ROMA FORMATION
Shale, sandstone
UPPER DEVONIAN
Sandstone conglomerate
Fault showing horizontal movement
Strike and dip of strata
Axis of anticline
Axis of syncline
Locality of spores and pollen
SCALE OF MILES
3 2 1 0 3

Fig. 3.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Sprigg (1961, p. 54) has stated : " A deep graben extending NNW–SSE through the Darling district of N.S.W. (in line with the Cambro-Ordovician belt of the Georgina Basin) developed finally to accommodate more than 20,000 feet of Upper Devonian-Lower Carboniferous sediments." The Mt. Jack No. 1 Bore penetrated 4,044 feet of Devonian sediments without reaching their base ; an aeromagnetic survey showed 6,000 feet of sediments between White Cliffs and the Mt. Jack-Peery Lake area, and 9,000 feet of sediments south of the Darling River in the area south-west of Cobar. Since Cambrian and Ordovician sediments were found to the west of the area, and since the aeromagnetic survey has shown the presence of a thick sedimentary sequence in the area, it is possible that the Devonian rocks in the area are underlain by Ordovician and Cambrian sediments. It may be added that a graben running north-south and containing about 8,000 feet of sediments has been revealed by the aeromagnetic survey north of Menindee, about 70 miles south-west of Wilcannia.

In the Mt. Jack No. 1 Bore the Devonian sediments are very fine and strongly silicified. Work by the author in the West Darling district has shown that the source of sedimentary material entering the Palaeozoic geosynclines was to the west ; hence coarser Devonian sediments may be expected west of the Mt. Jack area.

In this paper the author has attempted to elucidate the geology of a part of New South Wales where not much geological work has been done. A primary task was to determine the age of the Palaeozoic sediments, which has been achieved with the aid of the armoured fish which the author has described elsewhere. It may be added that, in contrast with the area studied in this paper, the area immediately to the east of it contains mainly Mesozoic sediments, but some similarities exist in the geology of both areas.

References

Balme, B. E., 1957.—Spores and pollen grains from the Mesozoic of Western Australia. *C.S.I.R.O. Aust., Coal Res. Sect. T.C.*, 25 : 1–48.

Dettmann, M. E., 1963.—Upper Mesozoic microfloras from south-eastern Australia. *Proc. roy. Soc. Vic.*, N.S. 77, 1 : 1–148.

Geological Survey of New South Wales, 1962.—Geological map of New South Wales. Department of Mines, Sydney.

Kenny, E. J., 1934.—West Darling district, N.S.W. Dept. Mines, Geol. Surv. Min. Res., 36.

Mulholland, C. St. J., 1940.—Geology and underground water resources of the East Darling district. N.S.W. Dept. Mines, Geol. Surv, Min. Res., 39.

Öpik, A. A., 1957.—Cambrian geology of the Northern Territory : in The Cambrian geology of Australia. Commwlth. Bur. Min. Res. Geol. Geophys. Bull., 49 : 25–54.

Pittman, E. F., 1895.—Report on a geological examination of the north-western portion of the colony, with special reference to the Cretaceous or artesian water bearing rocks. Annual Rept. Dept. Mines, N.S.W., 1894.

Rade, J., 1954.—Geology and sub-surface waters of the area north of the Darling River between longitudes 145° and 149° E, N.S.W. *Jour. roy. Soc. N.S.W.*, 88 : 24–32.

————, 1957.—Geology and sub-surface waters of the area east of Deep Well, Alice Springs district, Northern Territory. *Transact. roy. Soc. South Aust.*, 80 : 91–96.

————, 1964.—Upper Devonian fish from the Mt. Jack area, New South Wales, Australia. *Jour. Paleont.*, 38 : 929–931.

Relph, R. E., 1959.—The White Cliffs Opal Field, New South Wales. N.S.W. Dept. Mines, Technical Reports, 7 : 7–17.

Sprigg, R. C., 1961.—On the structural evolution of the Great Artesian Basin. Aust. Petr. Explor. Assoc. Pap. presented at the conference on the geology of South and Eastern Australia : 37–56.

Warner, R. A., and Harrison, J., 1961.—Discovery of Middle Cambrian fossils in New South Wales. *Aust. Jour. Science*, 23, 8 : 268.

EXPLANATION OF PLATE VII

Polygonal fracturing on the surface of Upper Devonian sandstones in the Mt. Jack-Peery Lake area.

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